NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE

No. 1569

A METEOROLOGICAL MEASURE OF MAXIMUM GUST VELOCITIES IN CLOUDS

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SUMMARY

Analytical considerations of the energy transformations in convective-type clouds indicate that a simple function of the height of convective activity and the horizontal-temperature variations might yield a measure of the gustiness in clouds. On this basis, qualitative relationships of the height of convective activity and the horizontal temperature spread with the maximum possible gust velocities are defined. These relationships show satisfactory agreement for available meteorological data as indicated by correlation coefficients of about 0.7 obtained between observed values of the maximum gust velocities and the meteorological parameters.

Based on experimental data, a simplified relation that may be used to forecast the maximum effective gust velocities within convective-type clouds is developed. This simplified parameter appears to give short-range forecasts that are correct within ±10 feet per second 95 percent of the time or within ±5 feet per second 67 percent of the time when used within the scope of the data presented.

INTRODUCTION

Forecasting the presence and intensity of atmospheric turbulence under all flight conditions is one of the meteorological problems of aviation. The solution of this problem has been sought for many years for better flight control, avoidance of dangerous routes, passenger comfort, and more economical operations. The entire problem includes the forecasting of turbulence due to wind shear, frontal activity, ground obstructions, and daytime heating, as well as the more manifest turbulence of convective-type clouds and thunderstorms. Although many investigators (references 1 to 3) have studied some phases of this problem, their results up to the present time have not provided a basis for the quantitative prediction of atmospheric turbulence.

An experimental investigation of the charactoristics of vertical gusts and associated meteorological conditions has provided a basis for the study of significant meteorological parameters for convective-type clouds. This investigation was made in 1941 and 1942 with an airplane suitably instrumented (reference 4) to measure vertical gusts. In addition, radiosonde ascents were made so that meteorological variables could be compared with the gusts encountered by the airplane. Although the gust data obtained have been published in a series of papers (for example, reference 4), efforts to correlate gust and meteorological data had been unsuccessful. A review of previous work indicated that the intensity of gustiness as defined by the maximum gust velocities at various altitudes was generally compared with the meteorological elements for corresponding altitudes. This approach, however, was believed to be too ambitious for present knowledge. A restricted goal, therefore, was chosen: to relate a single gust quantity to meteorological elements from a consideration of the elements at all altitudes.

On the basis of the restricted goal chosen a relationship between a gust quantity and the available energy was developed. The relationship was then evaluated for the available experimental data. In view of the promising results, the present paper presents the methods employed and the results which have been obtained.

SYMBOLS

f	fraction of horizontal cross-sectional area of convection cell which consists of rising air
g	acceleration due to gravity, feet per second per second
h	pressure altitudo, feet
H_c	vertical depth of convective activity for given air mass, feet
H_d	depth through which particle at height h within cloud can descend before being stopped by ground or colder surrounding air (figs. 1 and 2), feet
M, M_1, M_2, M_3	gust parameters as defined by equations (3), (4), (5), and (6), respectively
P	pressure at height h, millibars
ρ	density of air at height h, slugs per cubic foot

ρ_o	density of air at standard sea-level temperature and pressure, slugs per cubic foot
t	temperature, °C
T	temperature at height h, °C absolute
T_r	temperature acquired by saturated parcel of air rising from convective condensation level to level h (fig. 1), °C absolute
T_w	psuedo-wet-bulb temperature at height h (fig. 1), °C absolute
ΔT	$T_r - T_w$ for convective-type clouds at height h (fig. 1); $T - T_w$ for other type clouds at height h (fig. 2)
U_t	true vertical gust velocity at height h, feet per second
U_i	equivalent vertical gust velocity at height h, feet per second $\left(U_t\sqrt{\frac{\rho}{\rho_o}}\right)$
U_e	effective gust velocity, fictitious velocity assumed to act on airplane normal to flight path and determined by sharp-edged-gust formula from measured reactions of airplane (reference 5); effective gust velocity is measure of average true gust velocity U_t acting across the span of airplane (reference 6)
U_{e_t}	true effective gust velocity, effective gust velocity corrected for altitude by relation $$U_{e_t} = U_e\sqrt{\frac{\rho_o}{\rho}}$$ U_e and U_i are related to U_{e_t} and U_t, respectively, in same manner that equivalent airspeed is related to true airspeed
$\lvert U_e\rvert_{max}$, $\lvert U_{e_t}\rvert_{max}$	maximum value of $\lvert U_e\rvert$ and $\lvert U_{e_t}\rvert$ encountered during flight
w	vertical velocity of air or velocity of drafts, feet per second

ANALYTICAL CONSIDERATIONS

Inasmuch as turbulence is a complex phenomenon of the atmosphere, it cannot in general be defined by a simple characteristic. A characteristic of turbulence of interest to the structural engineer, meteorologist, and pilot, however, is the intensity of the vertical gusts. A quantity extensively used by the National Advisory Committee for Aeronautics as a measure of the true vertical-gust intensity is the effective gust velocity U_e. The maximum effective gust velocity $|U_e|_{max}$ has been found to be a useful parameter in the study of structural loads imposed on aircraft due to gusty air. In addition, recent evidence (reference 7) indicates that within convective clouds the maximum gust velocity resulting as it does from shearing action between the vertical draft and the surrounding air is related to the draft velocity. In view of the relationship of the maximum effective gust velocity $|U_e|_{max}$ to structural loads on aircraft and to meteorological variables, $|U_e|_{max}$ is utilized in this paper as the gust characteristic to be related to meteorological conditions.

The problem of deriving a meteorological expression for gust or draft velocities has usually been attacked by deriving a parallel expression for the kinetic energy of air particles. Several expressions for average air-particle velocities were derived about 40 years ago. (See reference 8.) On the basis of an assumed set of initial conditions, expressions were derived by considering three sources of kinetic energy:

(1) Temperature variations in each horizontal layer of a dry air mass

(2) Latent heat of condensation of water vapor

(3) Horizontal pressure distribution

Although the expressions are obtained from an ideal simplification of atmospheric processes, the qualitative relations may be valid and are subject to verification by experimental data.

From the first source of kinetic energy, the temperature variations in each horizontal layer of a dry air mass, the following expression for air-particle velocity is obtained (reference 8)

$$w = \sqrt{f(1 - f)gH_c \frac{T_{high} - T_{low}}{\left(T_{high}T_{low}\right)^{1/2}}} \qquad (1)$$

The second source of kinetic energy, the latent heat of condensation of water vapor, is usually studied by the well-known "parcel method" (reference 9). Consideration of the buoyant force in the atmosphere due to a density difference indicates that the average velocity acquired by a saturated parcel of air rising through the vertical depth H_c as a result of condensation is

$$w = \sqrt{2gH_c \frac{T_r - T}{T}} \tag{2}$$

An equivalent form of this expression is given in reference 10.

The third source of kinetic energy, the horizontal pressure distribution, is shown (reference 8) to give insignificant air-particle velocities.

Inspection of equations (1) and (2) indicates that the acquired air-particle velocities for both the major sources of kinetic energy are parallel functions of the height of the convective activity and the horizontal temperature spread. For this reason, a parameter of the form

$$M = \sqrt{H_c \frac{\Delta T}{T}} \tag{3}$$

might be expected to serve as a useful measure of draft and gust velocities in the atmosphere. Because the maximum value of equation (3) might be expected to give a measure of the maximum energy available for convective activity, it may be a useful measure of the maximum gust velocities. The quantity H_c used in equation (3) should be a measure of the depth of the convective action, although not necessarily the actual depth itself. Similarly, the quantity ΔT should be a measure of the horizontal temperature spread throughout the depth of the convective layer, although not necessarily the average spread.

In an effort to determine the best measure of the maximum gust intensity, three forms of the parameter M were considered:

$$M_1 = \left(\sqrt{h \frac{\Delta T}{T}}\right)_{max} \tag{4}$$

where h and $\frac{\Delta T}{T}$ are taken at the same altitude within the cloud. (Although the quantity h is defined as the pressure altitude above sea level, it is here used as an altitude above terrain. The difference for the present data, however, was too small to be of significance and the pressure altitude was, therefore, used for computational purposes.)

$$M_2 = \left(\sqrt{H_d \frac{\Delta T}{T}}\right)_{ax} \tag{5}$$

where H_d and $\frac{\Delta T}{T}$ are taken at the same altitude.

$$M_3 = \sqrt{\left(H_d\right)_{max}\left(\frac{\Delta T}{T}\right)_{max}} \tag{6}$$

where $\left(H_d\right)_{max}$ and $\left(\frac{\Delta T}{T}\right)_{max}$ are determined independently and are the maximum values for a given sounding.

These forms were selected in an effort to determine empirically the best measure of the maximum energy available for convective activity. The particular forms chosen are somewhat arbitrary, but they do attempt to measure the joint effect of maximum credible temperature spread and effective depth of convective action.

For convective-type clouds, ΔT is determined from the sounding in a manner similar to that used in reference 11; ΔT is the difference between a maximum and a minimum temperature. The maximum temperature is the temperature that a parcel of air would acquire if it were lifted from the convective condensation level to the height h. This temperature is shown as T_r in figure 1. The minimum temperature is the temperature to which unsaturated air at that level can be cooled by evaporation of cloud droplets and is the wet-bulb temperature which is nearly the same as the psuedo-wet-bulb temperature shown as T_w at h in figure 1.

For other than convective-type clouds which are not completely saturated, the maximum and minimum temperatures at h might be the air temperature T and the psuedo-wet-bulb temperature T_w, as shown in figure 2. The alto-cumulus clouds shown in the figure were present at the time of the sounding as well as during the flight.

The determination of H_d in M_2 is made in figures 1 and 2 by the following procedure: The moist adiabat through T_w at level h within the cloud is followed down to the base of the cloud and then the dry adiabat is followed until it reaches the ground level or it intersects the original sounding. For convective-type clouds, the layer of convective activity as measured by H_d will generally extend to the ground (fig. 1). In the case of morning soundings, such clouds may form after the sounding is taken. Due allowance for daytime heating must therefore be made on the adiabatic chart. For other type clouds, H_d may be considerably smaller than for convective-type clouds as shown in figure 2.

The value of $(H_d)_{max}$ in M_3 is the maximum value of H_d for a given sounding and is found independently of the height of the maximum temperature spread. For convective clouds, $(H_d)_{max}$ is generally equal to the observed heights of the cloud tops. These heights were obtained from estimates made by a flight observer.

APPARATUS

In order to obtain gust data, flight surveys of clouds were made with the XC-35 airplane as described in reference 4. The basic instruments installed in the airplane to measure gust intensities were the NACA air-damped recording accelerometer and the NACA airspeed recorder. These are standard NACA photographically recording instruments.

Meteorological data for the days of the flights were obtained with radiosonde equipment of the type then in use by the Navy (reference 12).

SCOPE AND SELECTION OF DATA

Gust and meteorological data were available for 29 flights of the XC-35 airplane at Langley Field, Va. Each flight consisted of from 1 to 20 cloud traverses at altitudes from 1,000 to 34,000 feet. For these flights, the intention was to make cloud surveys during the height of afternoon convective activity, but this procedure was not always possible because of forecasting and operating limitations. In most of the cases, measurements were taken in air-mass convective-type clouds. In only few flights was frontal activity of sufficient intensity to be considered an important factor. On several occasions when towering cumuliform clouds failed to develop, measurements were taken in other cloud types, such as stratocumulus, alto-cumulus, and alto-stratus.

The maximum effective gust velocity $|U_e|_{max}$ measured in clouds on each flight was used as a measure of the maximum gust velocity for the air mass. In one flight the maximum effective gust velocity was encountered in cirrus clouds. This gust velocity, however, was not used because it was judged to be due to wind shear and, therefore, measurements made in the other clouds present were used instead. It should be noted that the maximum effective gust velocity measured is not necessarily the maximum in the air mass since there is no assurance that the flight survey covered the maximum activity.

On each flight day, one or more atmospheric soundings were made. Although morning soundings were preferred, they were available on only 24 days. Afternoon soundings were consequently used for the other 5 days.

RESULTS

Meteorological data.- Atmospheric soundings were evaluated in accordance with standard procedures to obtain pressure, temperature, and moisture content at significant levels. An example of such data is given in table I. The same sounding is shown as a temperature-height curve in figure 1(b). The variables ΔT, $\frac{\Delta T}{T}$, h, and H_d are determined at each significant level of the sounding, and the quantities $(\Delta T)_{max}$, $\left(\frac{\Delta T}{T}\right)_{max}$, $\left(H_d\right)_{max}$, M_1, M_2, and M_3 are evaluated as indicated in table I. The data for all flights are summarized in table II.

Gust data.- The records of acceleration and airspeed from all traverses were evaluated to obtain the maximum effective and maximum true effective gust velocities for each flight. These values of $|U_e|_{max}$ and $|U_{e_t}|_{max}$ are given in table II.

Correlation analysis.- Correlation coefficients between the various meteorological quantities and the maximum effective gust velocities were determined according to standard methods (reference 13) and are given in table III. Figure 3 is an example of a scatter diagram showing the line of regression of the gust quantity $|U_e|_{max}$ on the meteorological quantity $\left(\frac{\Delta T}{T}\right)_{max}$. The limits of the standard error of estimate are also shown to indicate the reliability of the estimated values of gust velocity.

PRECISION

The measured quantities are estimated to be accurate within the following limits:

Atmospheric pressure, millibars	±8
Temperature, $^{\circ}C$	±1
Relative humidity, percent	±10
Effective gust velocity, feet per second	±3

Derived meteorological quantities, based on the preceding values, are estimated to have the following possible errors:

ΔT, $^{\circ}C$	±2
$\frac{\Delta T}{T}$	$\pm 7.4 \times 10^{-3}$

The wide range of possible error in the values of the h-term and the H_d-term leads to difficulties in assigning limits of error to these quantities. It is estimated that a range of ±500 feet would include the errors in most of the cases with average errors of about ±300 feet.

The use of the estimated errors in the temperature and height terms results in possible errors of ±6 in the parameters M_1 to M_3 with average errors of ±3.

DISCUSSION

Evaluation of gust-meteorological relations.- The correlation coefficients between gust and meteorological parameters in table III, averaging 0.7, are considerably higher, to the best of knowledge, than any that have been found between gust and meteorological data. The high degree of relationship indicates that the vertical depth of convective activity and the maximum credible horizontal temperature spread yield significant measures of the maximum effective gust intensities in clouds. Comparison of the correlation coefficients obtained using the meteorological parameters M_1, M_2, and M_3 indicates that, within the scope of the data presented herein, no significant differences exist among the several methods used to allow for the depth of convective activity.

It may be noted that although the parameters M_1, M_2, and M_3 were developed as measures of the true gust velocities, they have been used as measures of effective or equivalent velocities. Trial correlations between the meteorological parameters M_1 to M_3 and the values of the maximum true effective gust velocity $\left|U_{e_t}\right|_{max}$, table II, showed that the adjustment for altitude on the effective gust velocity had no appreciable effect on the degree of relationship obtained. The result may be due to the small range of altitude at which the maximum gusts were encountered inasmuch as about 70 percent of the maximum gusts were encountered at altitudes between 8,000 and 16,000 feet.

Table III also indicates that each of the quantities $(\Delta T)_{max}$, $\left(\frac{\Delta T}{T}\right)_{max}$, and $\left(\sqrt{\frac{\Delta T}{T}}\right)_{max}$, when correlated with the gust parameter, yields coefficients of the same order as the parameters M_1, M_2, and M_3. The high order of these correlations results from the high correlation noted in the table between $(\Delta T)_{max}$ and $\left(H_d\right)_{max}$. The pronounced dependence between $(\Delta T)_{max}$ and $\left(H_d\right)_{max}$ would therefore tend to reduce the efficiency of the combined use of these variables in the parameter M. The parallel relationship between $\left(\frac{\Delta T}{T}\right)_{max}$ and $\left(H_d\right)_{max}$ is discussed in more detail in the section entitled "Application to forecasting." In addition, the equivalent correlations found for $(\Delta T)_{max}$ and $\left(\frac{\Delta T}{T}\right)_{max}$ with $\left|U_e\right|_{max}$ are expected to be modified by data from other latitudes since T would have a wider range of value than observed in the present data. The fact that the correlations of $\left(\frac{\Delta T}{T}\right)_{max}$ and $\left(\sqrt{\frac{\Delta T}{T}}\right)_{max}$ with $\left|U_e\right|_{max}$ yield essentially equal coefficients would appear to be in disagreement with the analysis, but this discrepancy can readily be shown to be due to the small range of value obtained for $\left(\frac{\Delta T}{T}\right)_{max}$.

Application to forecasting.- In order to use the indicated relations between gust and meteorological parameters for forecasting, the meteorological variables must be measurable or predictable prior to the development of the clouds. The ΔT-term and the T-term satisfy this requisite, but the h-term and the H_d-term in M_1, M_2, and M_3 do not since their values depend upon an observer's estimate of the cloud bases and tops as well as on the soundings. Predicted values of the cloud bases and tops can conceivably be used to yield sufficiently accurate estimates of the h-term and the H_d-term. The investigation of this possibility is, however, beyond the scope of the present paper.

The correlation coefficient between $\left(\frac{\Delta T}{T}\right)_{max}$ and $|U_e|_{max}$ for the present data was about the same as those obtained between the parameters M_1 to M_3 and $|U_e|_{max}$. Because the term $\left(\frac{\Delta T}{T}\right)_{max}$ can be readily estimatod from the morning sounding, the possibility of using this term as a measure of the maximum effective gust velocity is suggested. The accuracy of using this simplified parameter was investigated and the regression line of $|U_e|_{max}$ on $\left(\frac{\Delta T}{T}\right)_{max}$ for the present data is illustrated in figure 3. The equation for the regression line of that figure is

$$|U_e|_{max} = 638\left(\frac{\Delta T}{T}\right)_{max} - 2.9 \tag{7}$$

The standard error of estimate is 5.2 feet per second. If equation (7) is used to forecast $|U_e|_{max}$, reference 13 indicates that predictions within the scope of the present data should be correct within ±10 feet per second 95 percent of the time or within ±5 feet per second 67 percent of the time. In view of the accuracy of the data and the methods of analysis employed, the regression line (equation (7)) is judged to give a significant measure of the maximum effective gust velocity within the scope of the weather conditions investigated.

The effectiveness of the simplified parameter $\left(\frac{\Delta T}{T}\right)_{max}$ as a measure of the maximum effective gust velocity for the present data is derived from the statistical dependence noted between $\left(\frac{\Delta T}{T}\right)_{max}$ and $(H_d)_{max}$. In an effort to check this relation for data from another latitude, the correlation between $\left(\frac{\Delta T}{T}\right)_{max}$ and $\left(H_d\right)_{max}$ was evaluated for data recently obtained at a more southerly latitude. This evaluation indicated that the high correlation for $\left(\frac{\Delta T}{T}\right)_{max}$ and $\left(\Delta T\right)_{max}$ with $\left(H_d\right)_{max}$, noted in table III for data obtained in the vicinity of Langley Field, Va., did not exist. The height of convective activity, on the average, appears greater for the data from the southerly latitude; whereas the maximum credible horizontal temperature spread showed no similar tendency. In addition, the depth of convective activity will generally be expected to decrease in winter. For these reasons, equation (7) would be expected to yield accurate forecasts of $\left|U_e\right|_{max}$ only when used within the scope of the present data.

CONCLUDING REMARKS

The correlation coefficients between gust and meteorological parameters, averaging 0.7, indicate that the maximum value for a given sounding of the meteorological parameter M gives a significant measure of the maximum gust velocity in convective-type clouds. The parameter

$$M = \sqrt{H_c \frac{\Delta T}{T}}$$

where

H_c vertical depth of convective activity for given air mass

$\frac{\Delta T}{T}$ relative horizontal temperature spread

Within the limited scope of the data, this parameter can yield satisfactory estimates of the maximum gust velocities in clouds.

The simplified parameter defined by the maximum value, for a given sounding, of $\frac{\Delta T}{T}$ would appear to yield equally accurate estimates of the maximum effective gust velocities within the scope of the data presented. Forecasts made with this simplified parameter can be expected ~~to~~ be correct within ±10 feet per second 95 percent of the time or within ±5 feet per second 67 percent of the time.

Although the present data consist almost entirely of traverses through cumuliform clouds, the analysis indicates that the methods employed might possibly be extended to almost all cloud types. Data covering more complete cloud representation would permit investigation of this possibility. In addition, data covering other latitudes and seasons would provide a basis for the determination of a general parameter and relationship.

Langley Memorial Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va., June 25, 1947

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TABLE I

ANALYSIS OF SOUNDING TAKEN AT LANGLEY FIELD, VIRGINIA

[September 10, 1941; 0805 EST]

Pressure, P (mb)	Temperature, T (°C abs.)	Mixing ratio (gram/kg)	Temperature spread, ΔT (°C)	Pressure altitude, h (ft)	Relative temperature spread, $\Delta T/T$	$\sqrt{h \frac{\Delta T}{T}}$	Convective depth, H_d (ft)	$\sqrt{H_d \frac{\Delta T}{T}}$
1022	299	19.0	----	------	------	--	------	--
998	301	17.8	----	------	------	--	------	--
982	300	17.5	----	------	------	--	------	--
838	291	11.9	4.6	5,200	0.0157	9	5,200	9
802	291	8.8	6.0	6,300	.0206	11	6,300	11
789	290	8.4	6.5	6,800	.0224	12	6,800	12
748	289	5.8	8.0	8,200	.0277	15	8,200	15
702	285	6.0	7.0	9,800	.0246	16	9,800	16
609	277	1.9	11.6	13,450	.0418	24	13,450	24
597	277	1.3	12.3	13,900	.0444	25	13,900	25
533	273	.7	10.7	16,700	.0392	26	16,700	26
400	259	.6	7.0	23,500	.0271	25	23,500	25
340	250	-----	8.0	27,300	.0320	30	27,300	30
300	243	-----	8.2	30,000	.0337	32	30,000	32
177	216	.03	1.5	39,800	.0069	17	------	--
155	211	-----	----	------	------	--	------	--

Evaluation of meteorological parameters: Cumulus-congestus cloud traversed during flight; base and top of cloud estimated at 4000 and 30,000 feet, respectively.

$$(\Delta T)_{max} = 12.3^\circ \mathrm{C}$$

$$\left(\frac{\Delta T}{T}\right)_{max} = 0.0444$$

$$\left(H_d\right)_{max} = 30{,}000 \text{ ft}$$

$$M_1 = \left(\sqrt{h \frac{\Delta T}{T}}\right)_{max} = 32$$

$$M_2 = \left(\sqrt{H_d \frac{\Delta T}{T}}\right)_{max} = 32$$

$$M_3 = \sqrt{\left(H_d\right)_{max} \left(\frac{\Delta T}{T}\right)_{max}} = 36$$

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TABLE II

SUMMARY OF GUST AND METEOROLOGICAL DATA

Date of flight	Gust data		Meteorological data				
	$\lvert U_e \rvert_{max}$ (fps)	$\lvert U_{e_t} \rvert_{max}$ (fps)	$(\Delta T)_{max}$ (°C)	$\left(\frac{\Delta T}{T}\right)_{max}$	M_1	M_2	M_3
3-24-41	13	14	5.6	0.0209	13	8	8
4-4-41	6	7	7.8	.0283	15	11	11
4-10-41	16	26	6.1	.0212	14	12	17
5-9-41	11	13	5.7	.0216	17	17	17
5-23-41	28	45	13.9	.0514	35	35	39
7-1-41	22	34	10.0	.0406	35	35	35
7-3-41	18	25	11.9	.0442	35	35	36
7-31-41	25	34	12.2	.0453	27	27	33
8-12-41	34	49	12.2	.0447	34	34	42
8-23-41	28	44	10.5	.0386	37	37	36
9-4-41	22	27	8.7	.0324	28	28	32
9-5-41	26	33	9.6	.0395	33	33	35
9-10-41	31	39	12.3	.0444	32	32	36
10-2-41	16	19	10.0	.0363	18	18	20
6-30-42	18	20	8.7	.0317	15	15	17
7-2-42	14	16	8.1	.0311	26	26	27
7-14-42	16	19	11.6	.0414	24	24	25
7-27-42	13	14	7.0	.0251	24	24	24
7-28-42	21	26	9.3	.0376	24	24	25
7-29-42	19	22	11.1	.0431	22	22	25
8-20-42	13	15	9.6	.0348	23	23	23
9-2-42	25	27	8.7	.0317	11	11	16
9-4-42	18	21	8.4	.0318	17	17	21
9-9-42	19	22	9.6	.0387	23	23	27
9-10-42	18	21	10.6	.0402	28	28	30
9-17-42	16	19	10.4	.0439	22	22	26
9-18-42	34	48	12.7	.0496	32	32	34
9-19-42	38	52	13.5	.0502	32	32	34
10-23-42	26	31	10.4	.0398	21	21	23

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TABLE III

CORRELATION COEFFICIENTS BETWEEN GUST AND

METEOROLOGICAL VARIABLES

[Number of observations, 29]

Variables		Correlation coefficient
Meteorological	Gust	
M_1	$\lvert U_e \rvert_{max}$	0.62
M_2	$\lvert U_e \rvert_{max}$	.64
M_3	$\lvert U_e \rvert_{max}$	.72
$\left(\frac{\Delta T}{T}\right)_{max}$	$\lvert U_e \rvert_{max}$	.71
$\sqrt{\left(\frac{\Delta T}{T}\right)_{max}}$	$\lvert U_e \rvert_{max}$	.68
$\left(\Delta T\right)_{max}$	$\lvert U_e \rvert_{max}$	.72
$\left(H_d\right)_{max}$	$\lvert U_e \rvert_{max}$	.60
$\left(\frac{\Delta T}{T}\right)_{max}$ and $\left(H_d\right)_{max}$	------	.54
$\left(\Delta T\right)_{max}$ and $\left(H_d\right)_{max}$	------	.54

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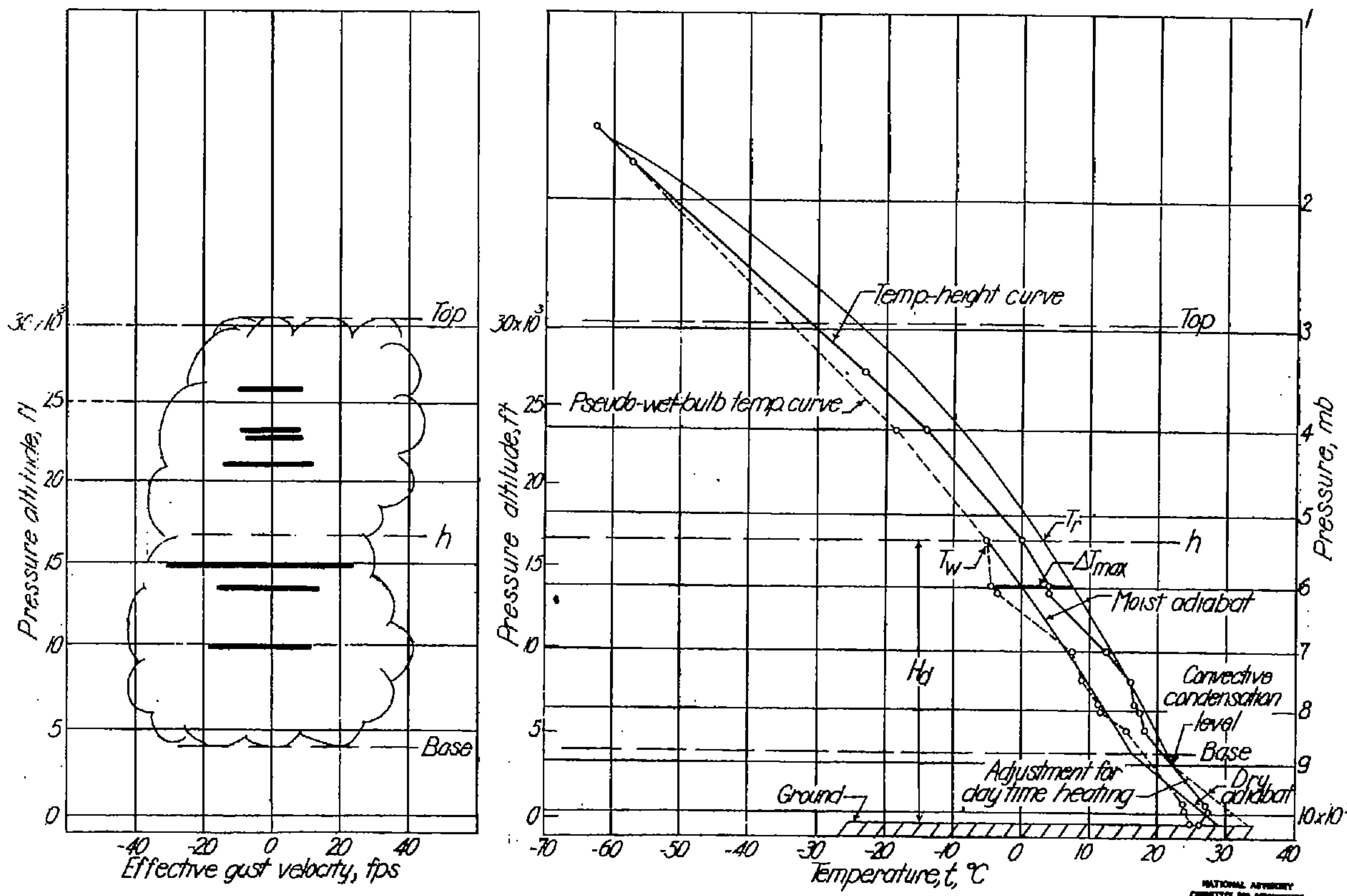
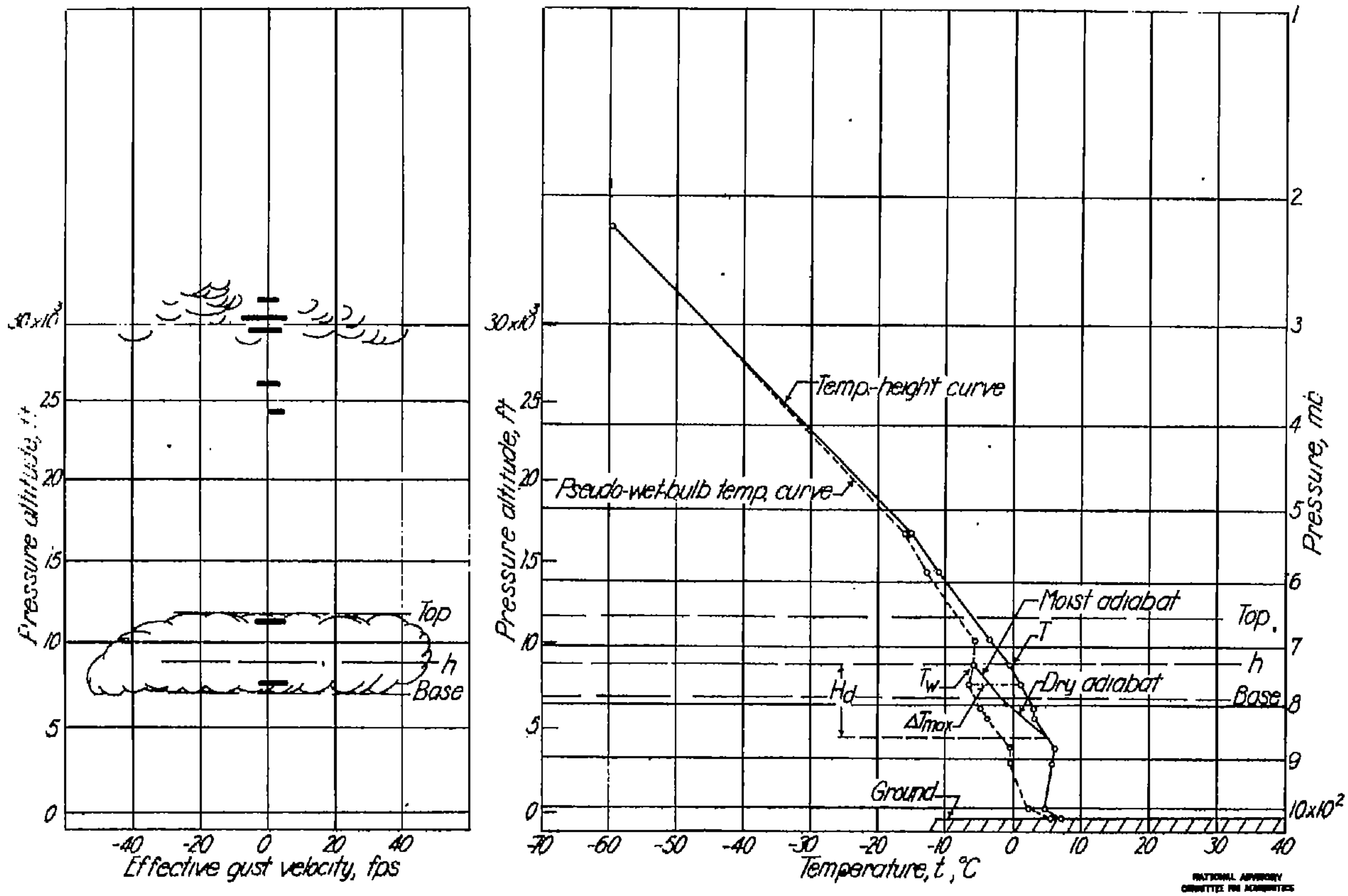


(a) Maximum effective gust velocity measured at various altitudes; 1413 to 1613 EST.

(b) Atmospheric sounding; 0805 EST.

Figure 1.- Atmospheric sounding and gust measurements. September 10, 1941.



(a) Maximum effective gust velocity measured at various altitudes, 1140 to 1343 EST.

(b) Atmospheric sounding; 0630 EST.

Figure 2.- Atmospheric sounding and gust measurements. April 4, 1941.

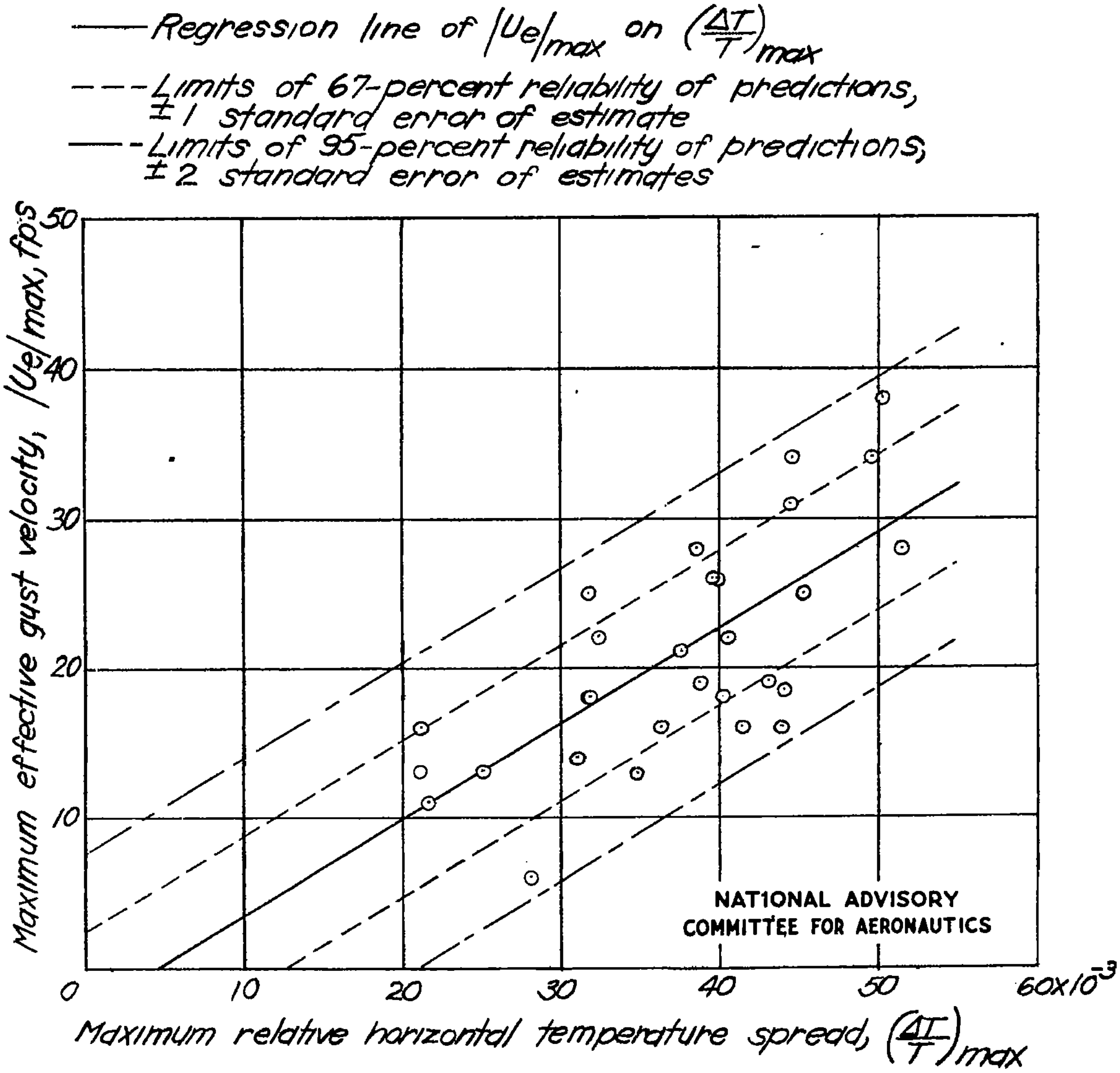


Figure 3.—Scatter diagram of maximum effective gust velocity plotted against maximum relative horizontal temperature spread for each flight.